N65-29811
(ACCESSION NUMBER)
11
(PAGES)
(NASA CR OR TMX OR AD NUMBER)
(THRU)
1
(CODE)
14
(CATEGORY)

FACILITY FORM 602

X-612-65-192

NASA TMX-55263

A TRIAXIAL ELECTRON DETECTOR

GPO PRICE $ ______

CFSTI PRICE(S) $ ______

Hard copy (HC) 1.00

Microfiche (MF) .50

ff 653 July 65

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APRIL 1965

NASA

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A Triaxial Electron Detector

A hypothetical sounding rocket experiment for the study of Polar Cap Absorption events would be designed to investigate the primary proton flux, the reactions which occur in the atmosphere, both ionic and nuclear, and perhaps the composition of the incoming beam. It would be aimed at understanding the conditions in the atmosphere, since satellite experiments are more suitable for time variation studies, the detection of small events, and the use of such events to study the conditions in interplanetary space.

The inclusion of a suitable electron detector in such an experiment simplifies the interpretation of the results. Primary electrons have never been detected, but this is hardly possible in a sounding rocket experiment. The electrons produced as a result of the ionization of the atmosphere, having a temperature of over 200^oK, will only be detected by an instrument going down in energy range to zero if, in addition, the potential of the rocket is zero or positive. This is not normally the case. A high energy component of electrons, indicating coincident auroral effects, should be looked for in order to differentiate its effects from those of the heavier particles, for example in the interpretation of riometer observations.

Such a detector should analyze a wide energy range in detail, from rocket potential up to at least 10 keV, good time resolution, rapid spectral scanning and adequate sensitivity response in several narrow angular windows is of advantage in using the movement of the vehicle to determine the pitch angle distribution of the incoming electrons.

The sensitivity of the detector we describe is from $6x10^5$ electrons per cm^2 sec steradian to more than $6x10^{10}$ electrons per cm^2 sec steradain.

The electron detector performs a differential energy analysis on electrons which reach the vehicle from three orthogonal acceptance cones of size $6\frac{1}{2}$ degrees x 10 degrees. Electrons that diffuse into the entrance slits of the instrument are first accelerated to 100 eV above their original energy. This assures their being comfortably above the detector's low energy threshold, and has the additional advantage of reducing the range of potentials needed for the electrostatic analyzer plates which follow the accelerating grid. These cylindrical analyzers deflect particles of the correct energy per unit charge through 127° using potentials applied symmetrically above and below the 100 Volt accelerating voltage. All three analyzers are stepped simultaneously through the range of electron energies from 0 to 10 keV. This range is covered in 16 steps whose energy admittance is $\pm$ 8% and whose spacing is approximately logarithmic. The stepping sequence is shown in Fig. 1. The deflection potential returns to zero from the last and highest voltage step in a smooth exponential decay scanning the entire energy range. This step-wise ascent and exponential descent simplifies data analysis and also assures that no portion of the spectrum will be missed. Except for the common power supply which provides the deflection voltage for the three sets of analyzer plates, each section of the instrument operates independently of the other two, with its own electronics, power supply, and telemetry channel.

After the energy of the electrons is selected by the analyzer they enter the detector - a windowless electron multiplier produced under the commercial name of "channeltrons". These channeltrons are operated as null detectors in the following way. The output current of the channeltron is compared to a standard current, which in our present arrangement has the value of 3×10^{-9} amperes. The difference between these two currents is used in a servo loop to control the high voltage and thus the gain of the channeltron. A simplified block diagram of this system is shown in Fig. 2. In this method of operation the output current remains very close to the value of the standard current, since an imbalance between them of 5% can be detected. The channeltrons have a gain-vs-applied high voltage characteristic which is stable and close to logarithmic over more than five decades of gain as shown in Fig. 3. Therefore this arrangement has the advantage that a logarithmically compressed analog telemetry signal can be derived simply as a fraction of the applied high voltage. The telemetry signal is normally zero to +5v, compatible with a standard rocket transmitter.

The servo-system has several other advantages.

(1) It discriminates against gain changes in the channeltron, since this effect, which is discussed below, is a function of output current. The servo-system never allows this to rise above the low value of 3×10^{-9} Amperes.

(2) The simplicity of this system allows several detectors to observe in different directions with low weight and power requirements but at the same time retaining a wide dynamic range.

(3) This arrangement lends itself to in-flight calibration. This is achieved by using a radioactive source in the folowing way. For no input to the channeltron, the applied high voltage and gain are at a maximum. An input flux from a pure β-emitting source will stabilize the high voltage at a value slightly below maximum and allow variations in gain over a range of about 10 to be determined. This source can located in such a position that the deflecting potential on the analyzer plates will sweep most of the β-particle flux away from the channeltron when electron measurements are being taken. Thus no dynamic range is lost in ordinary operation. Experience has shown that the shape of the gain characteristic does not change with shifts in gain thus permitting this method of one-point calibration.

(4) This servo-system has a rapid response time, allowing fluctuations of 10 cps. to be followed. This has been measured by observing the high voltage response to square wave input variations. Fig. 4 shows a oscillogram of this variation in high voltage across the channeltron when the input is a square wave.

This system of three detectors thus requires one deflection voltage supply and three servo-systems, which are mounted in a circular arrangement shown in Fig. 5. The diameter of the cyclinder is 6 inches, and the length is 5 inches, not counting the extending ends of the analyzers. These dimensions were chosen so that the package could be mounted in a variety of existing sounding rockets, in either a vertical or horizontal position. The weight of the instrument is under four lbs. and power consumption is two watts at 28v. D.C. One telemetry channel is required for each of the three detectors with a fourth channel used for deflection voltage information. The energy analysis arrangement described above is one appropriate for the study of electron fluxes along the orbit of the EGO satellite. It is easy to modify this step layout; somewhat less easy to increase the upper energy of 10 keV. This could, however, be raised to approximately 20 keV by some sacrifice in power and sensitive area. The number of energy steps can of course be varied, and the time spent on each step reduced if necessary to approximately ¼ second.

As part of a research program in which this instrument will be flown on an EGO spacecraft, we have undertaken detailed studies of the long term gain-stability of the channeltron multiplier. By using a channeltron design which arose from these studies, and by taking reasonable precautions against contaminating the semi-conducting surface of the tube, the gain change can be limited to a factor of three for the one year lifetime of this spacecraft. Thus for rocket flight any change in channeltron gain is a completely negligible effect.

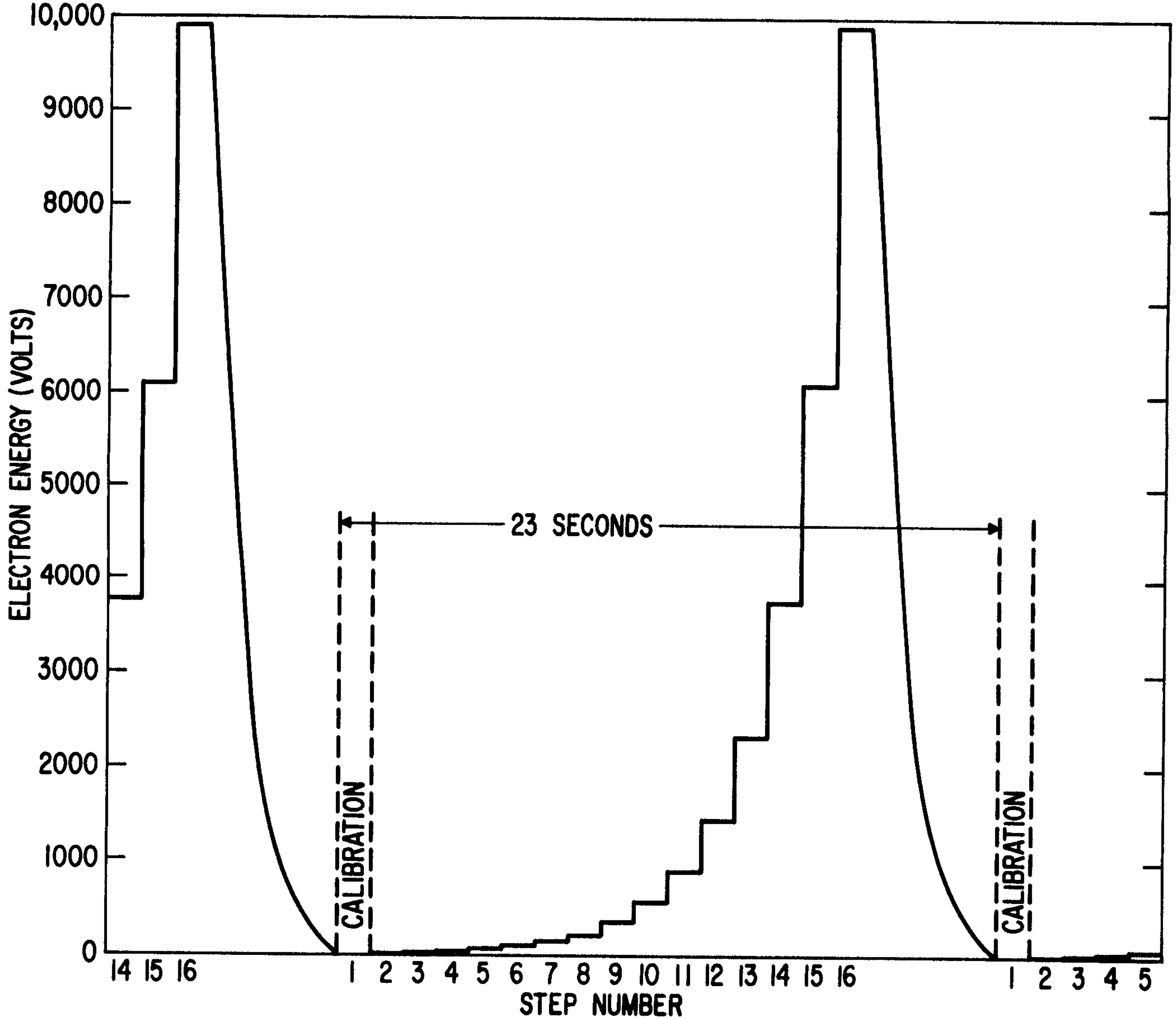

Figure 1. An example of a sequence of energy steps applied simultaneously to all three analyzers. For the spacecraft version of this instrument, this entire sequence takes 23 seconds and includes an in-flight calibration step.

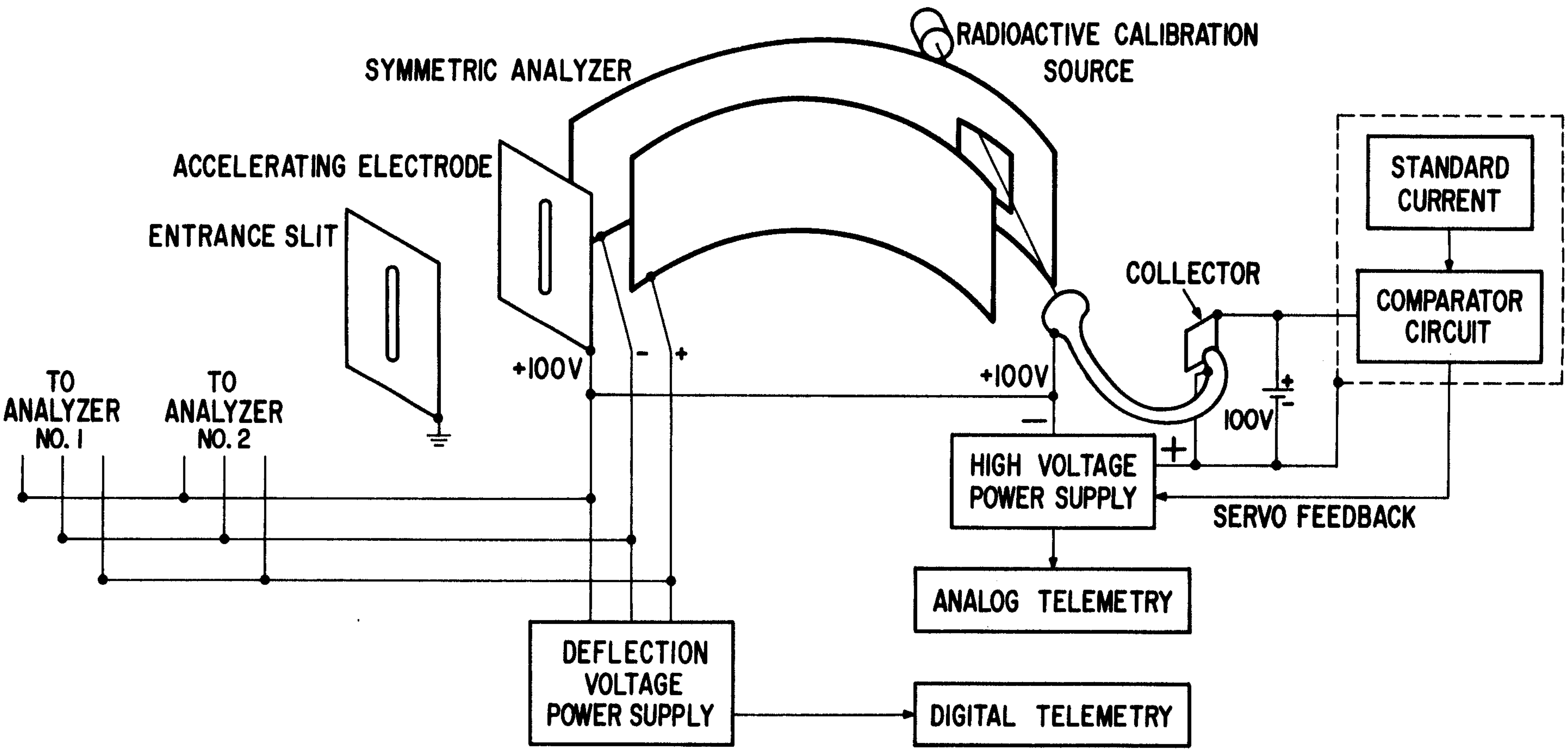

Figure 2. Block diagram of electronics for Triaxial Electron Analyzer.

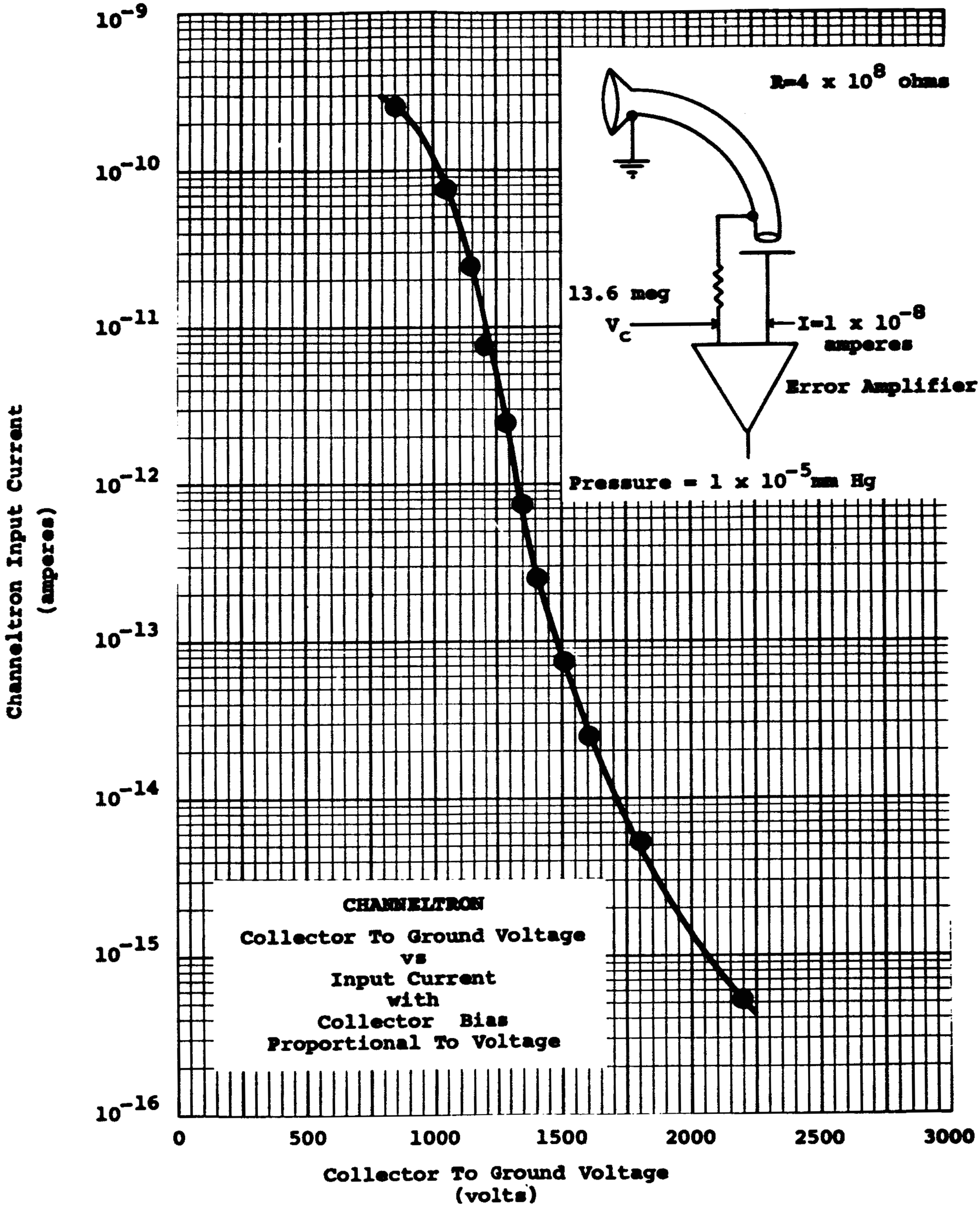

Figure 3. High voltage output of the servo system as a function of input current to the channeltron. Dynamic range is more than five decades. A fraction of high voltage forms telemetry analog data.

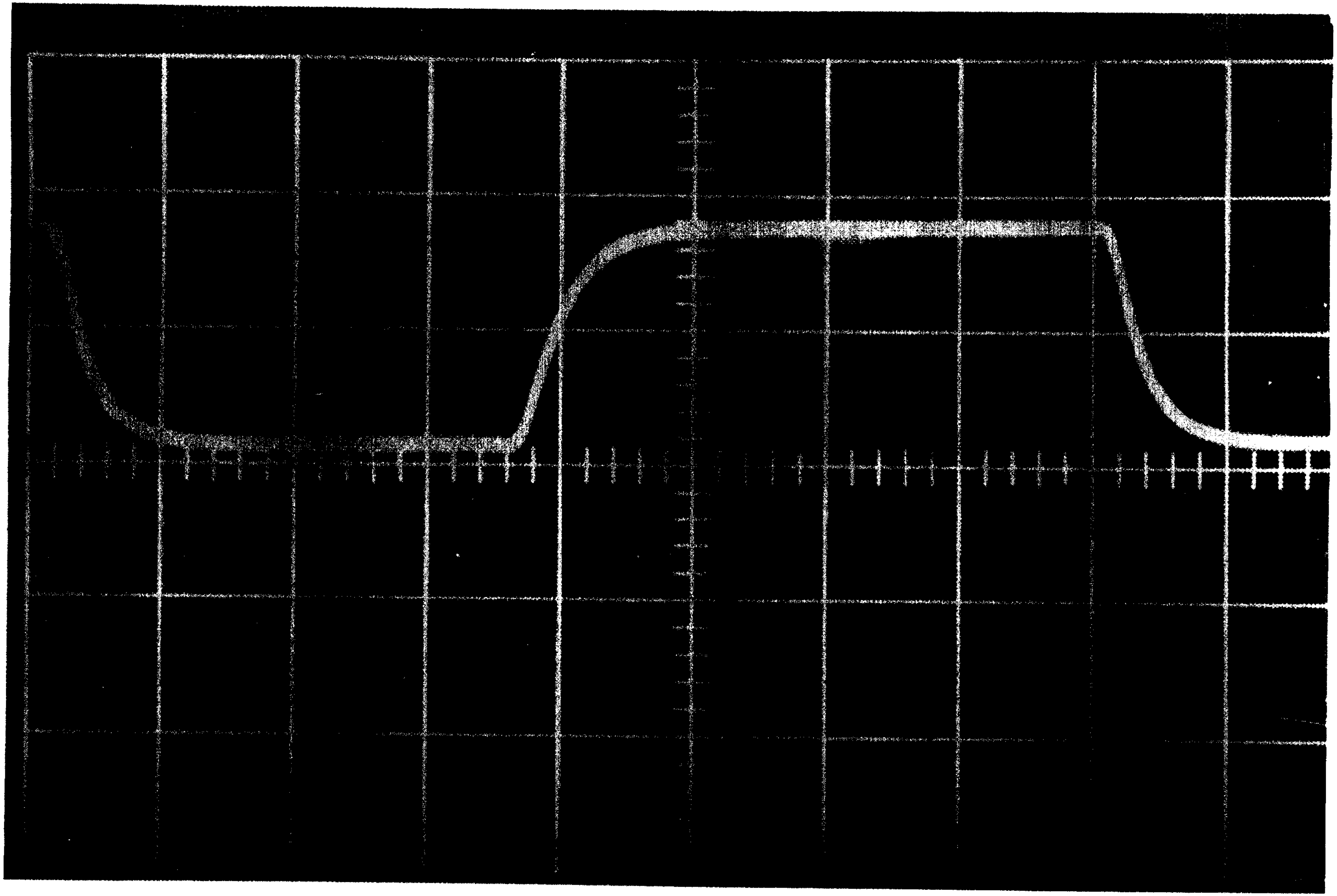

Figure 4. Response of servo system to a square wave input current to the channeltron. (0 to 1.25 x 10^{-10} amperes). Time for system to stabilize at new voltage is approximately 0.1 sec. Horizontal scale is 0.1 sec per square. Vertical scale is 500V per square.

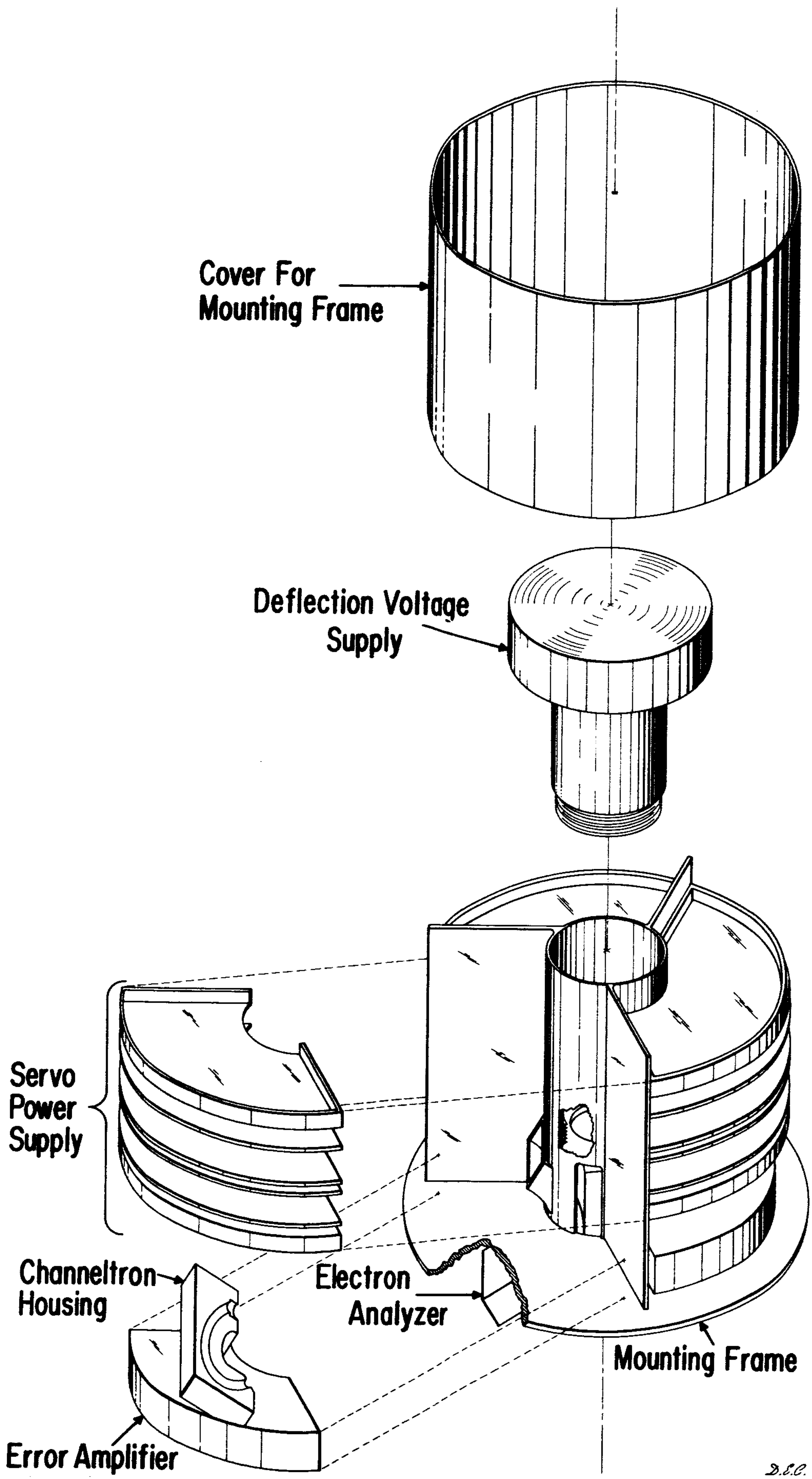

Figure 5. Structural arrangement of Triaxial Electron Analyzer.